COUPP, the "Chicagoland Observatory for Underground Particle Physics"

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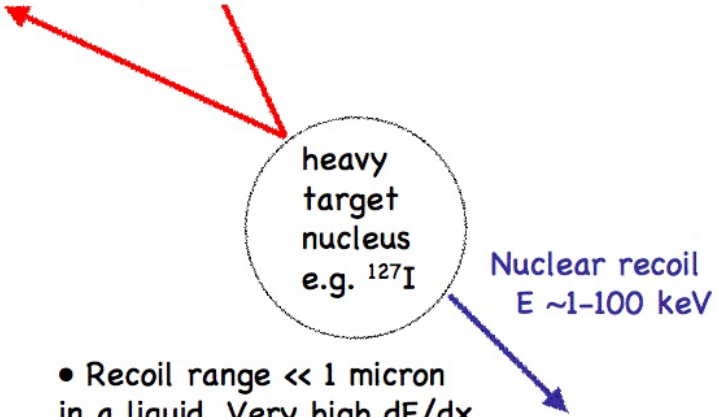
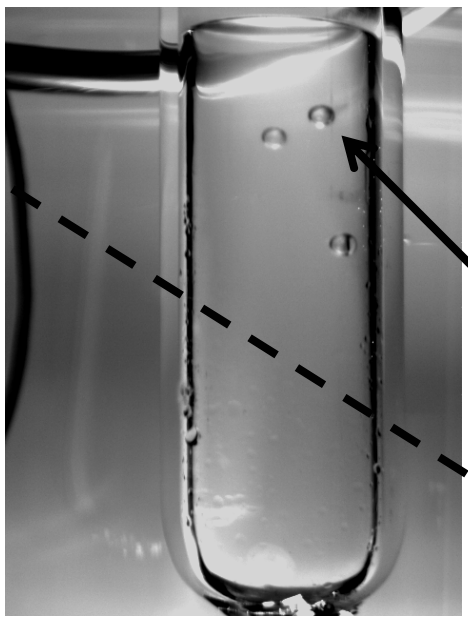
Dark matter particle from galactic halo
velocity ~300 km/s
mass 10–10000 GeV (SUSY?)

WIMP



- Recoil range << 1 micron in a liquid. Very high dE/dx

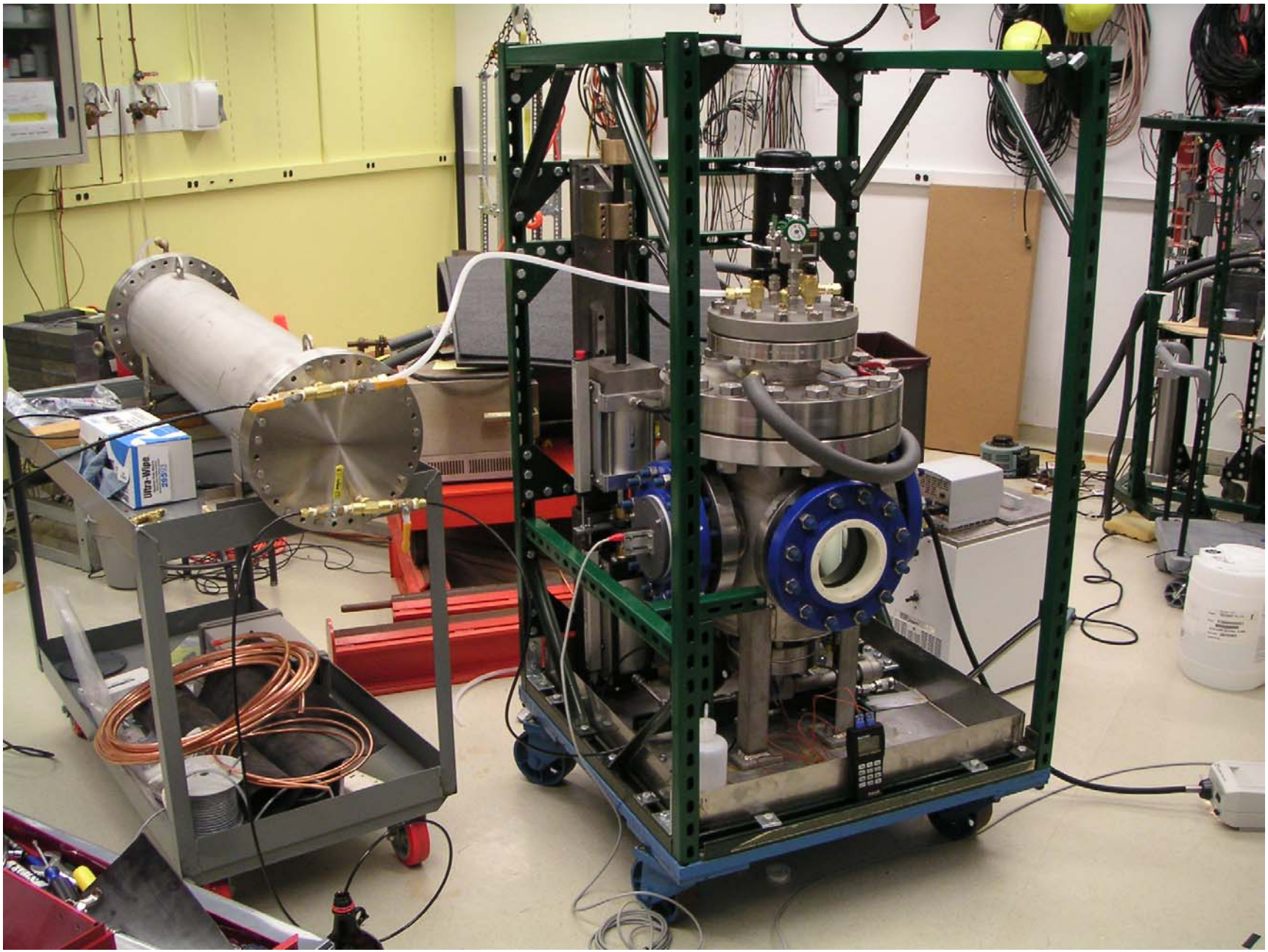
Signal is <u>single</u> bubble
Initiated by nuclear recoil



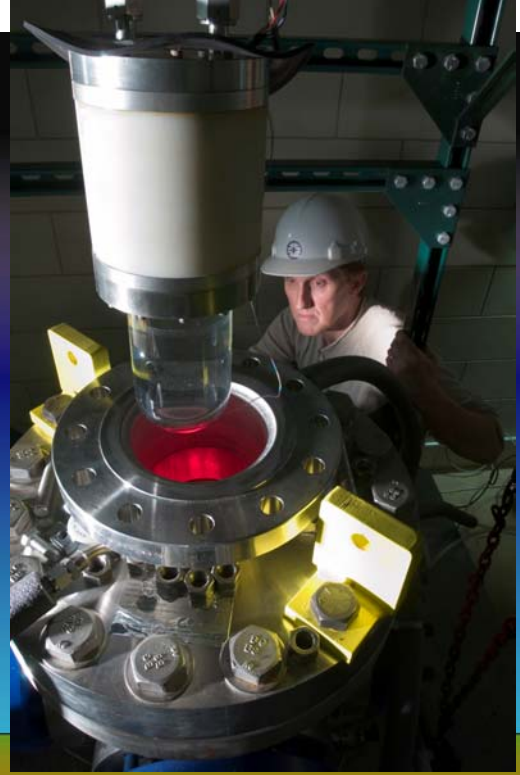
neutron-induced events can be identified by multiple bubbles

<u>NO</u> bubbles for MIPs

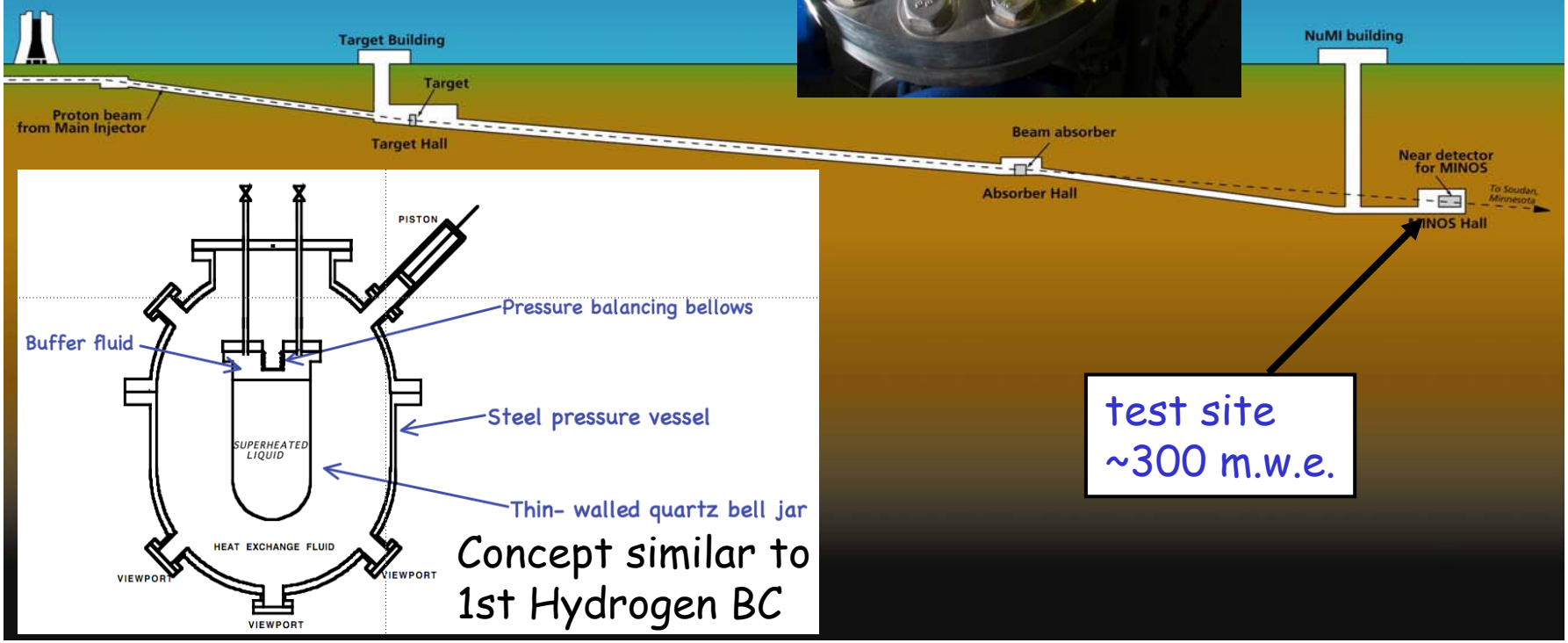
1- Liter Bubble Chamber



COUPP @ NuMI Tunnel Project (Fermilab Test Beam Proposal T945)



2kg (1l) CF_3I chamber built at UC installed May '05



Concept similar to 1st Hydrogen BC

Continuous Operation: December '05 to ~~July~~ September '06

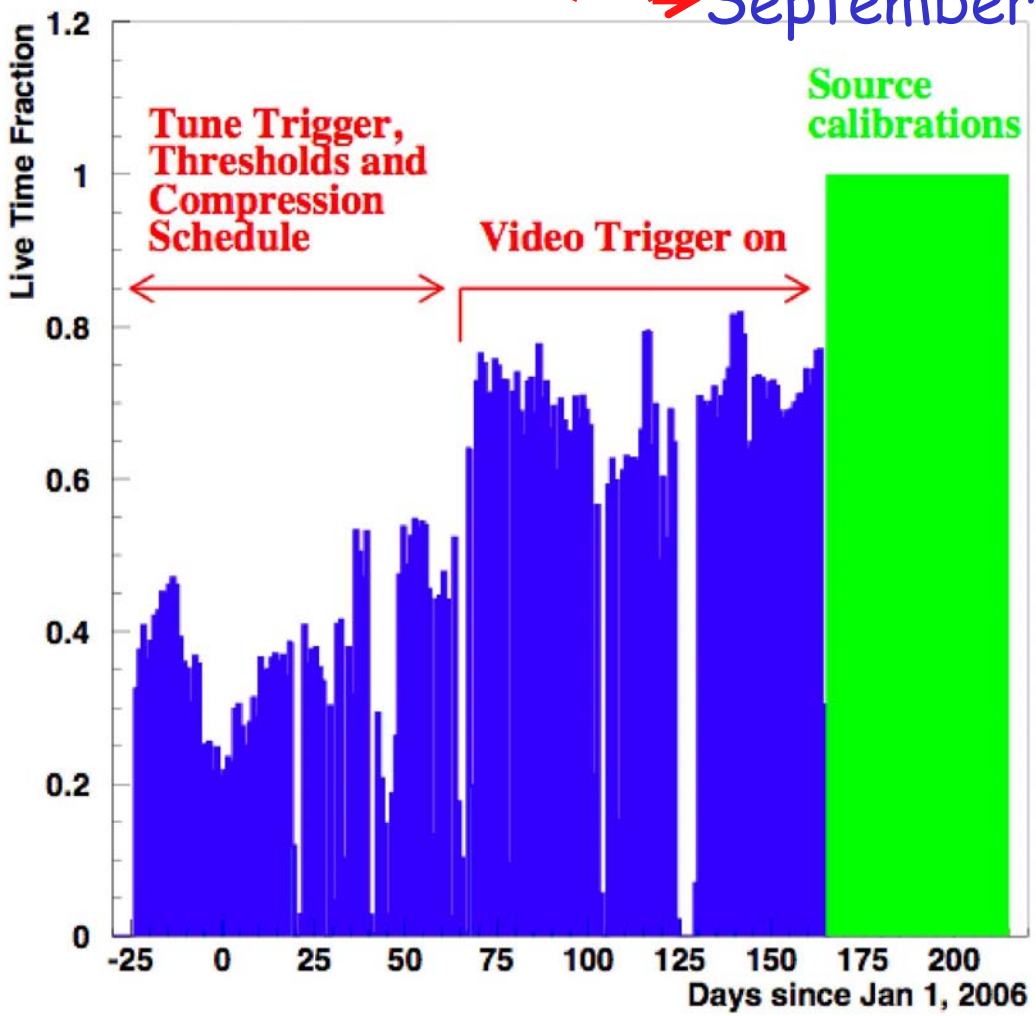
223 days in run
84k expansions
100 seconds mean
superheated time

98 live days
= 44% of calendar time

~70% live time after stabilization

35.5k bubbles counted

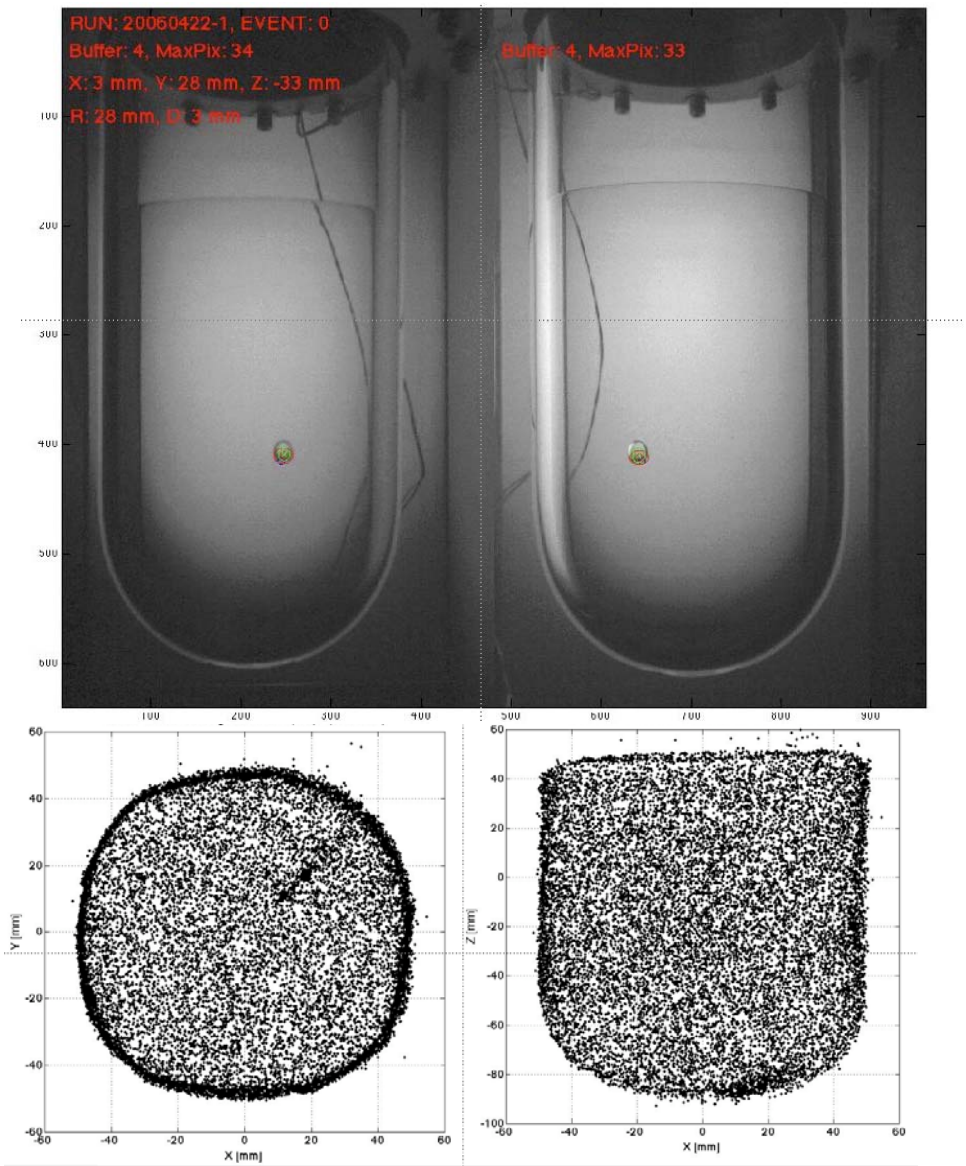
250 GB in Enstore



Goals of TBP T945:

- Demonstrate reliable operation.
- Study backgrounds (they were expected!)
- Calibrate with sources: γ, n.

Stereo view of a typical event in 2 kg chamber

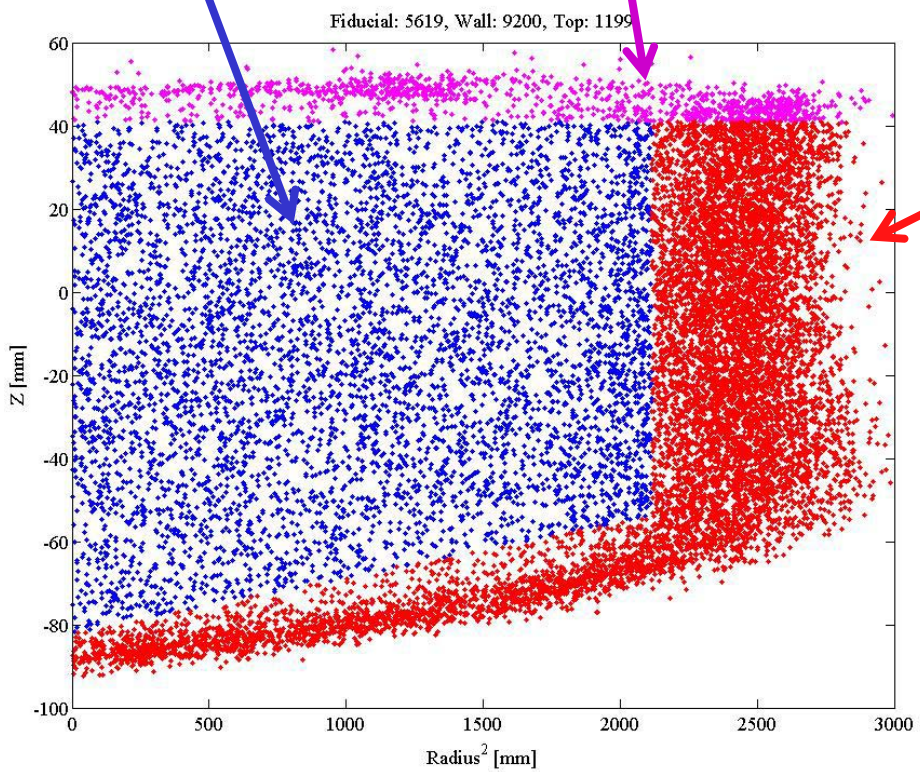


Spatial distribution of bubbles (~1 mm resol.)

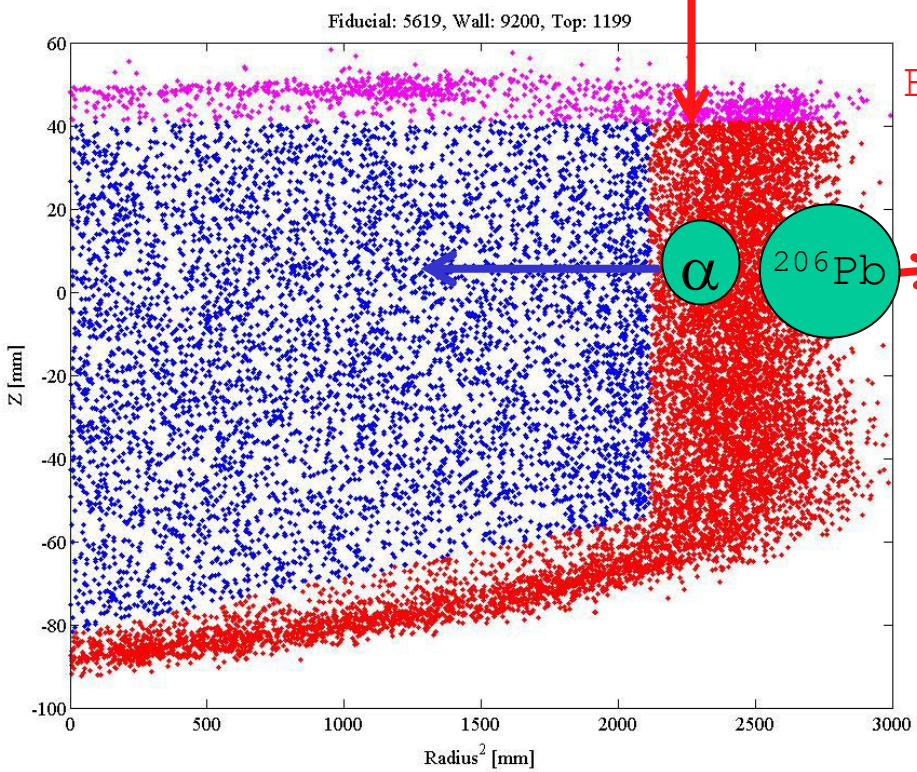
surface boiling events

"wall" events

bulk events



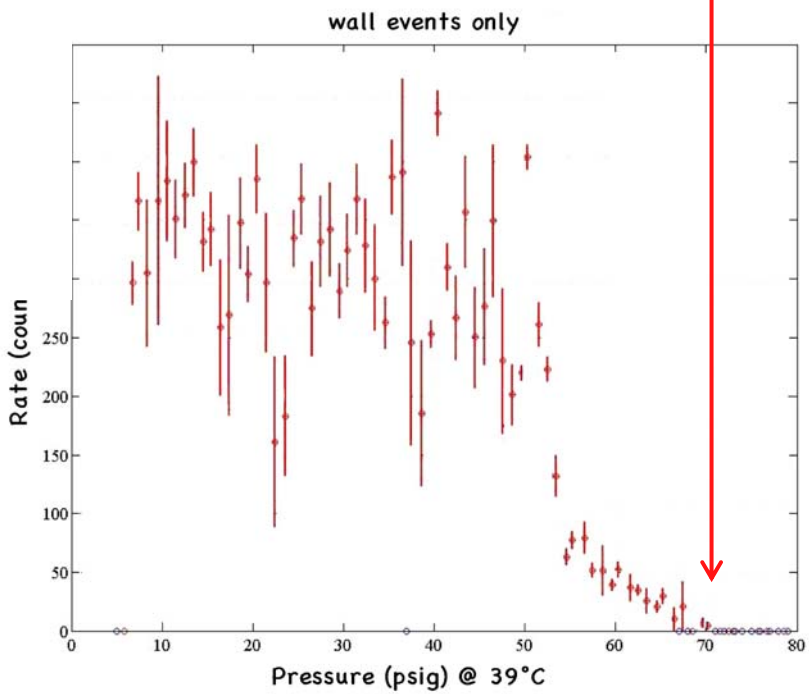
1) Excess surface nucleations from Rn daughter implantation



Example, consider ^{210}Po->^{206}Pb:

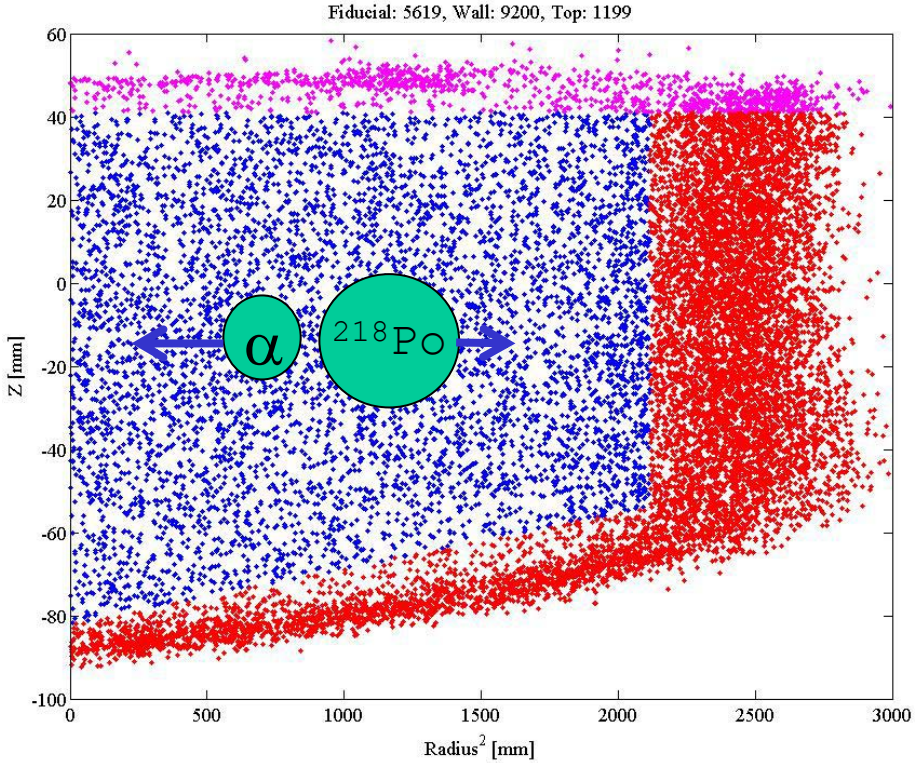
E_α = 5.4 MeV E_R= 105 keV

Tell-tale signature:
onset of α-sensitivity
expected at ~70 psig
(@39° C)



- Rate is consistent with ~200 days of exposure during quartz vessel storage in typical fresh-air Rn concentrations

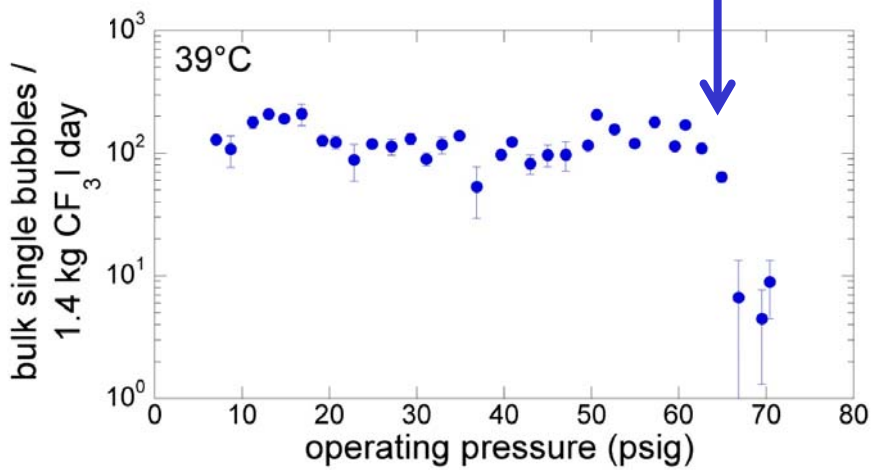
2) Radon Decays Presently Dominate Bulk Events



Example, consider ^{222}Rn->^{218}Po:

E_α = 5.5 MeV E_R= 102.6 keV

Monochromatic Line at 100 keV



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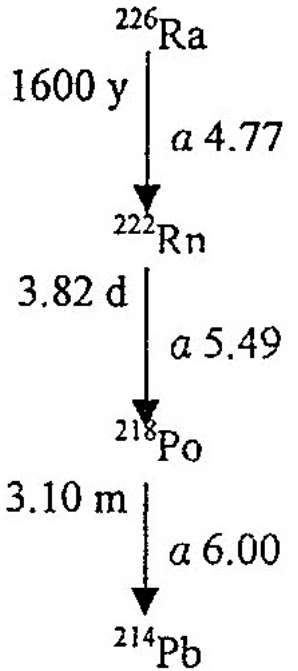
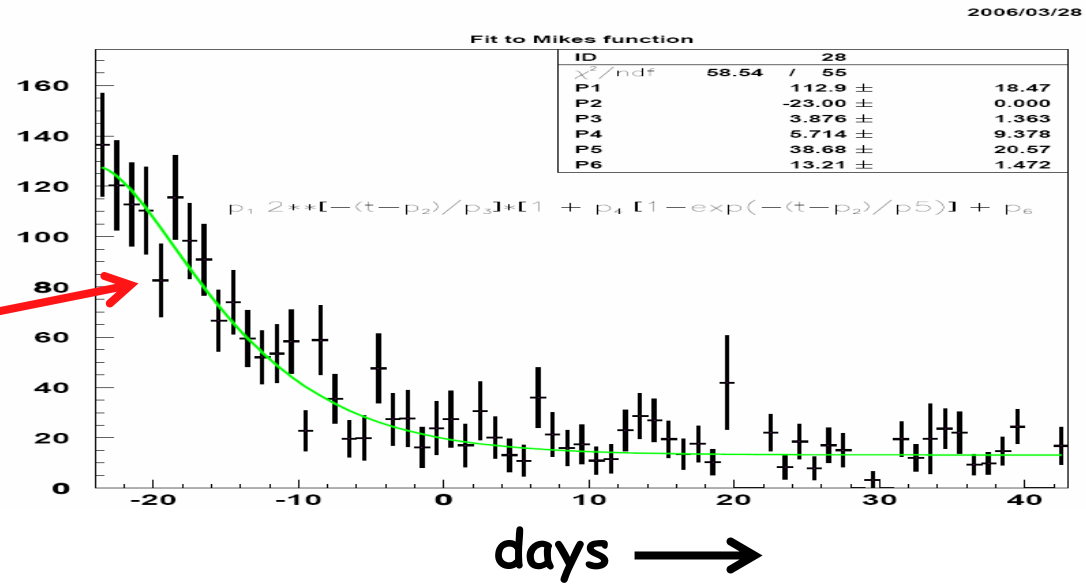
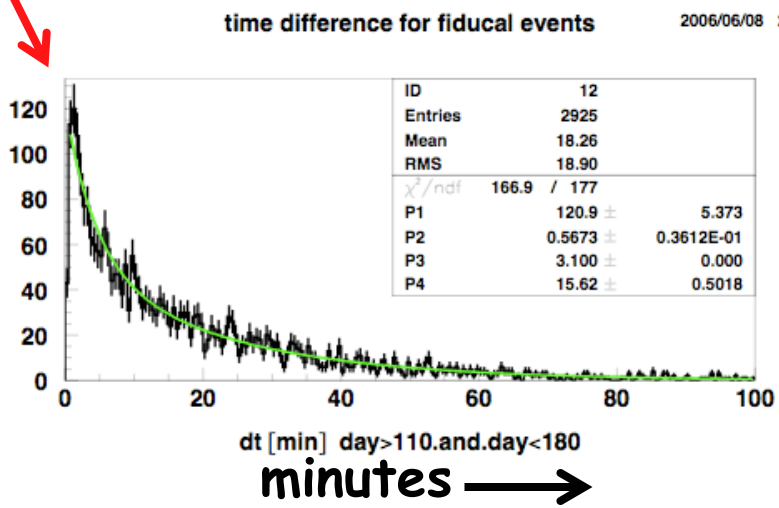






$$(t) = A \cdot \left(e^{-t/\tau} + \frac{\tau}{\tau'} \cdot e^{t_{rec}/\tau} \cdot e^{-t/\tau'} \right) + C \cdot e^{-t/\tau''}$$

$= 4.4\text{min}\ (^{218}Po);\ t_{rec} = recomp.time$

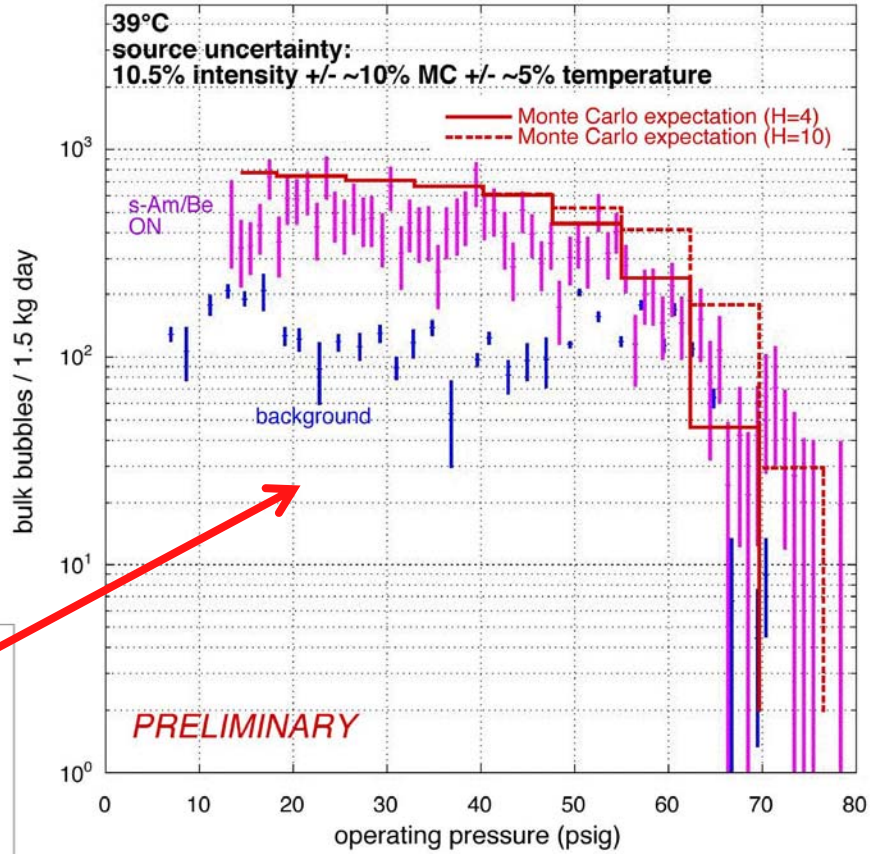
$,C,\tau',\tau'' \longleftarrow fit$

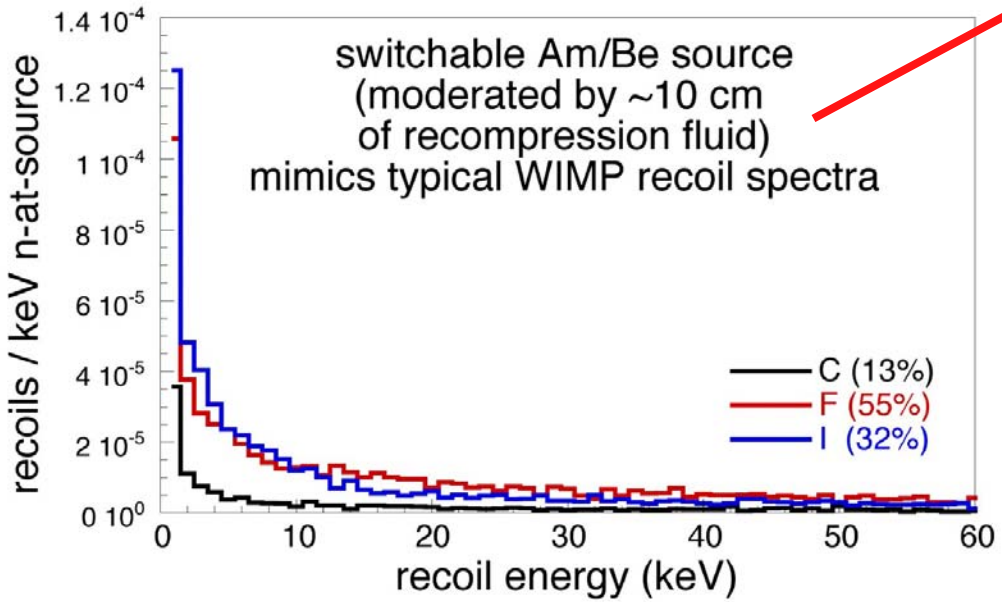
se fit to A to find ^{218}Po events, this is raction $e^{-t_{rec}/\tau}$ of total of ^{222}Rn present data

Switchable Am/Be (5 n/s)

in situ neutron calibration

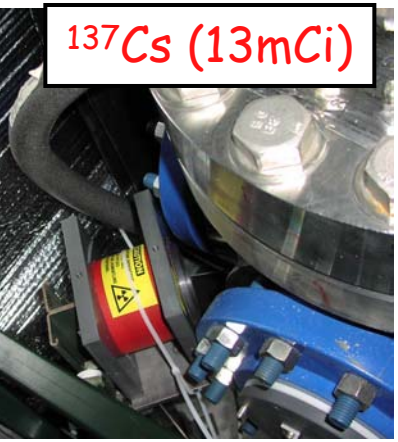
O(0.2) n/day when OFF. Second generation design produces none.



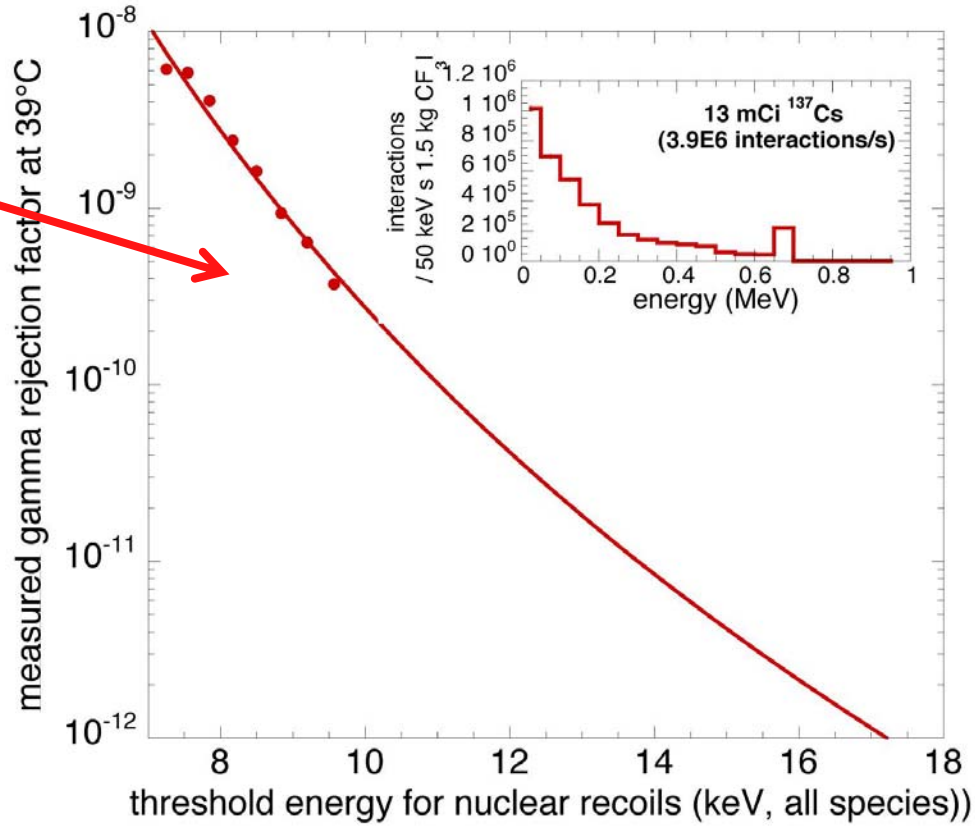


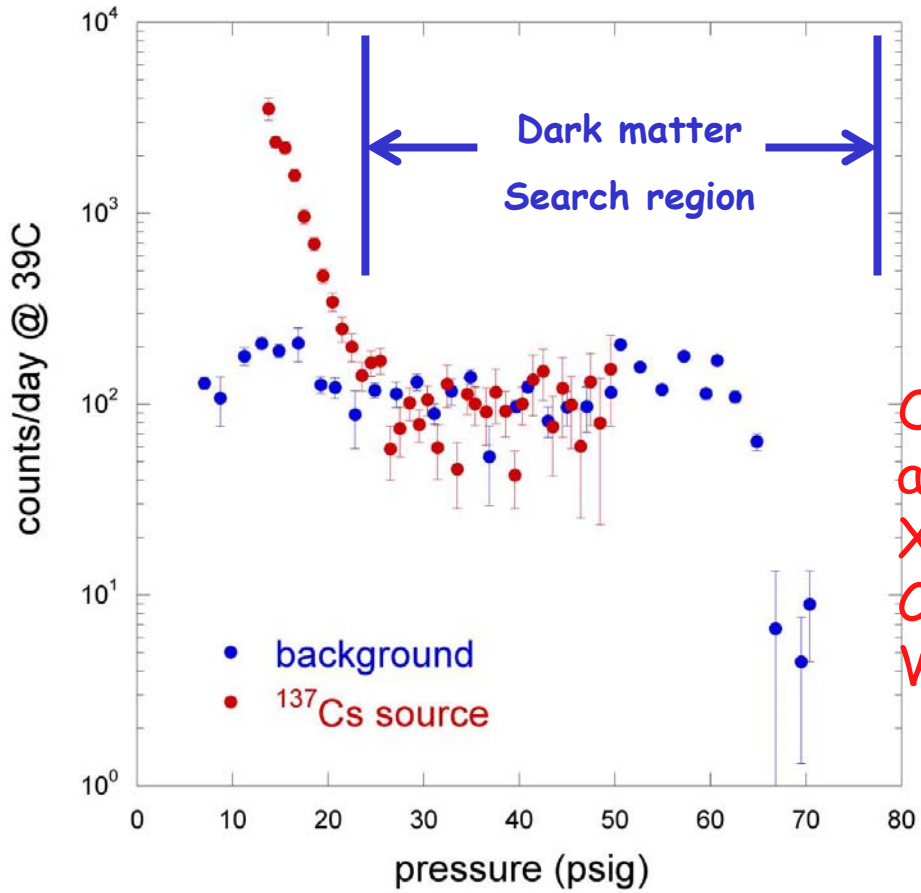
S-Am/Be can be used for ~daily calibration of chamber response (important when searching for DM modulations)

Spectacular rejection for electron recoils



Best MIP rejection factor measured anywhere (<10^{-10} INTRINSIC, no data cuts)





Other experiments as a reference:
XENON ~10^{-2}
CDMS 10^{-4}-10^{-5}
WARP ~10^{-7}-10^{-8}

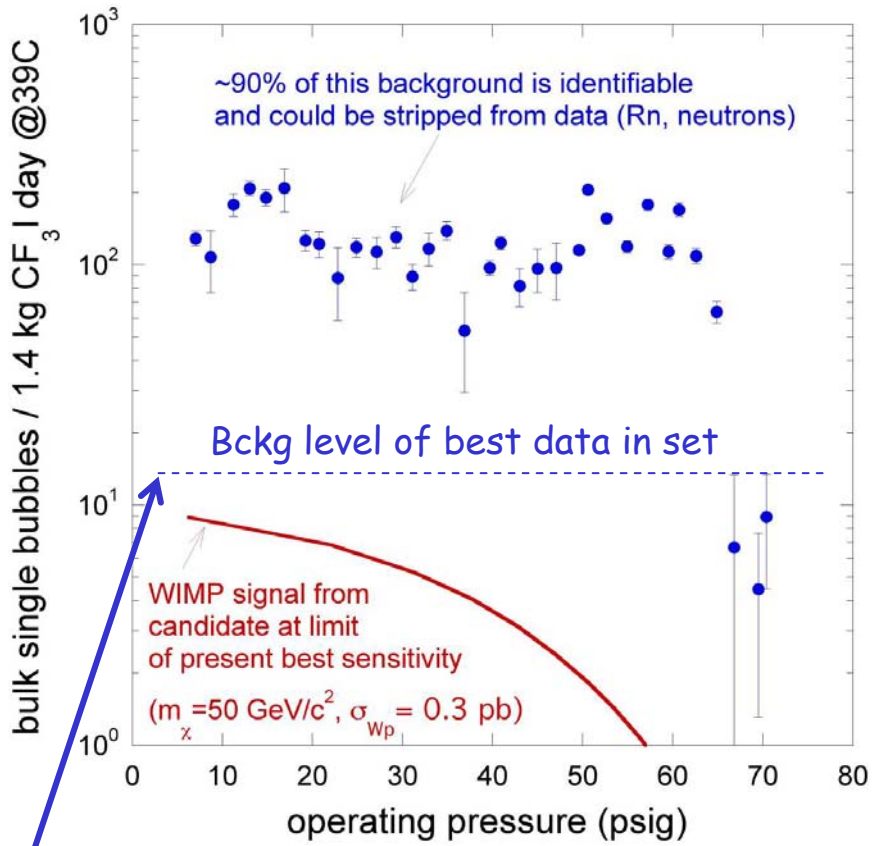
^{14}C betas not an Issue for COUPP (typical O(100)/kg-day)
<u>No need for high-Z shield nor attention to chamber material selection</u>

Physics Reach at Fermilab Site

Goal for immediate next phase: reduce background to <1 event per liter per day

Improvements for next fill:

- new quartz vessel
  - etched after manufacture
  - special storage & handling
- metallic gaskets
- non-thoriated welding
- TAMApure H_2O (< 10^{-15} U and Th)
- CF_3I U,Th measured to ~10^{-14} sensitivity (ongoing AMS@ANL), use of nitric acid scrubbing column if finite value found
- electropolished storage vessels for CF_3I
- Attention to U,Th in dust (class 100 conditions, limited exposure, improved cleaning)

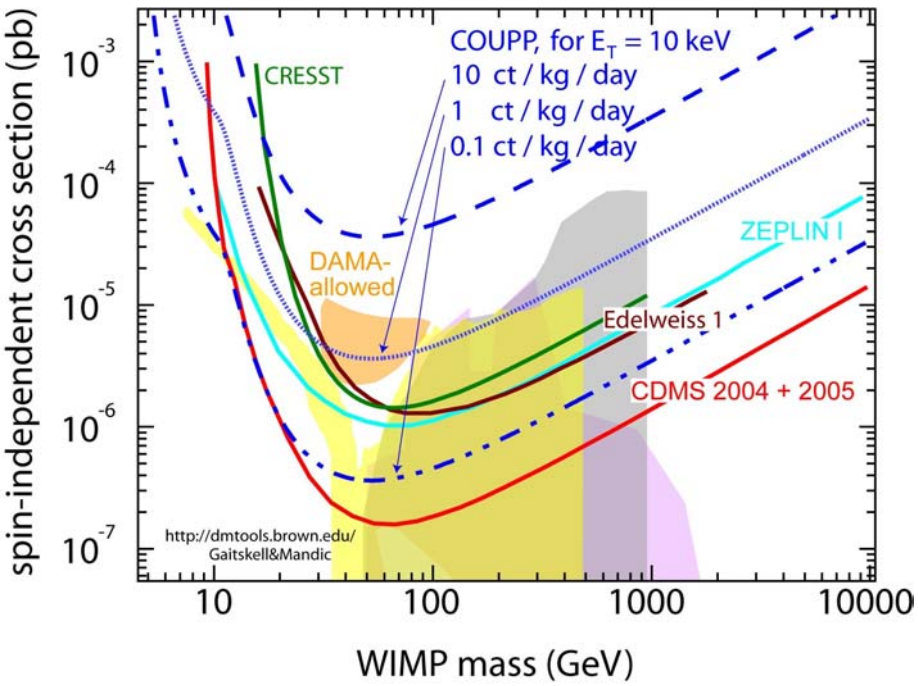


~55 kg-d of data (29°C @ 7.5 psig) exhibit a diminished Rn fraction (due to T-dependence): background rate of 13+/-1 bubbles/day (E_{thr}=17 keV)

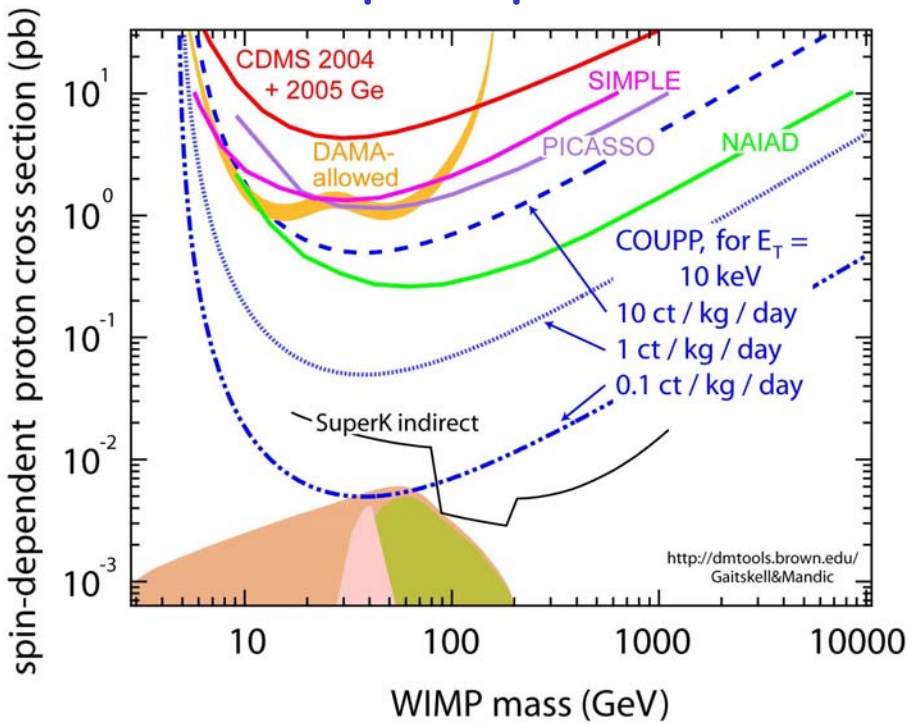
Physics Reach at Fermilab Site

Goal for this phase: reduce background to <1 event per liter per day

Spin-independent



Spin-dependent



Three projections are offered: ~10c/kg-d can be extracted from present data. ~1c/kg-d expected from simulated (μ,n). ~0.1c/kg-d is for 90% efficient μ veto. A further reduction to ~0.01 c/kg-d can be possible (simulated gallery n's percolate through 30 cm polyethylene shield at that level).
By then better than 10^{-15} U,Th needed (World best is KAMLAND @ ~10^{-18}).

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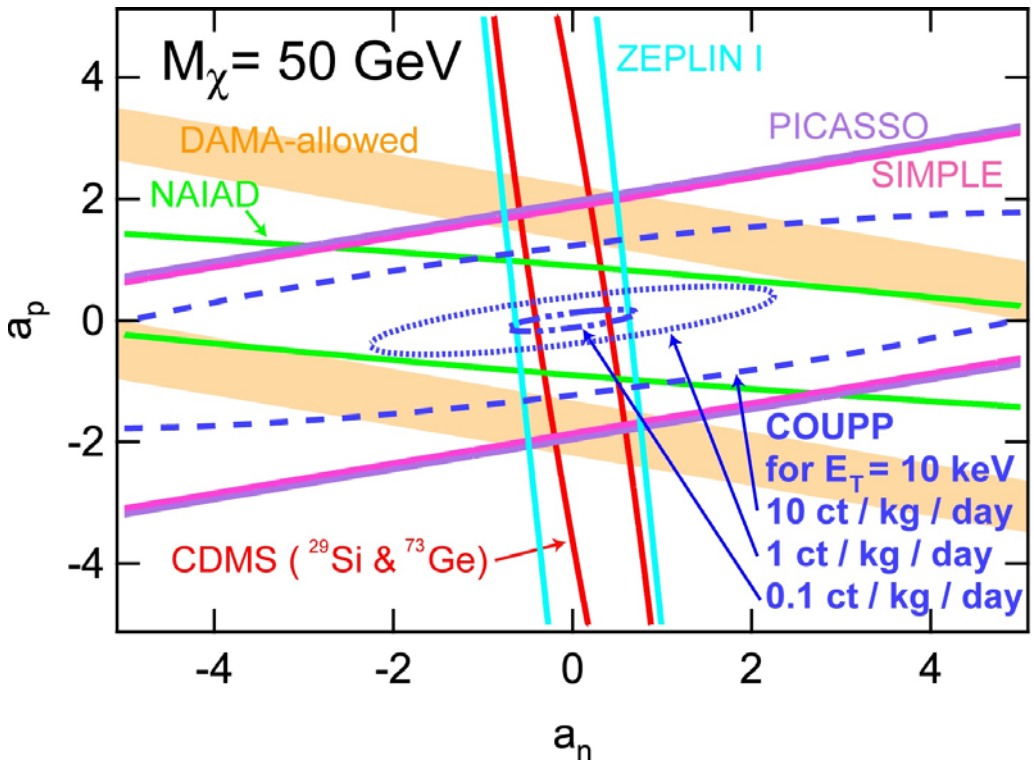

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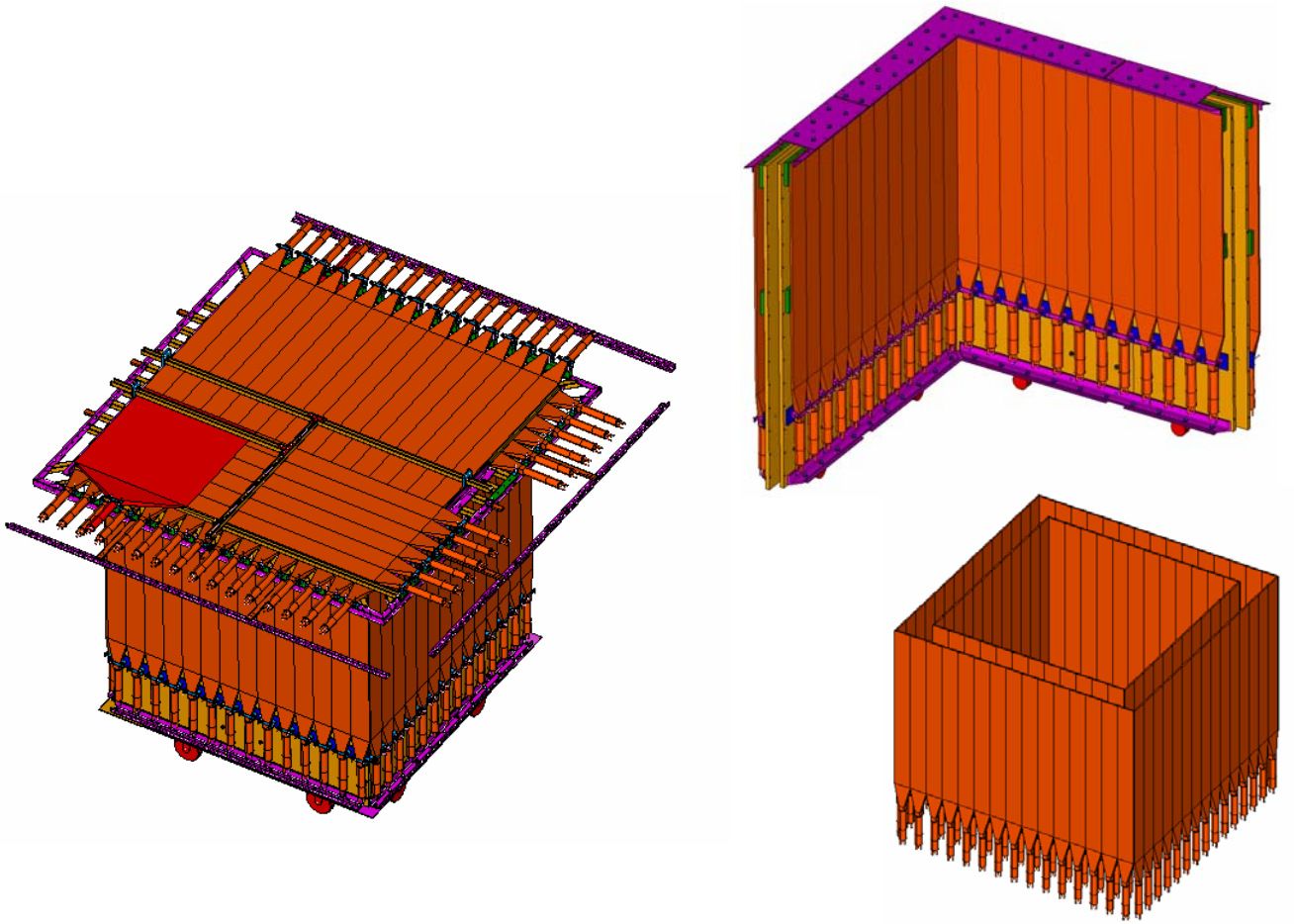
COMING ATTRACTIONS: Muon Veto

- Approximately 150 KTeV scintillation counters
- Assembly complete. Commissioning underway.

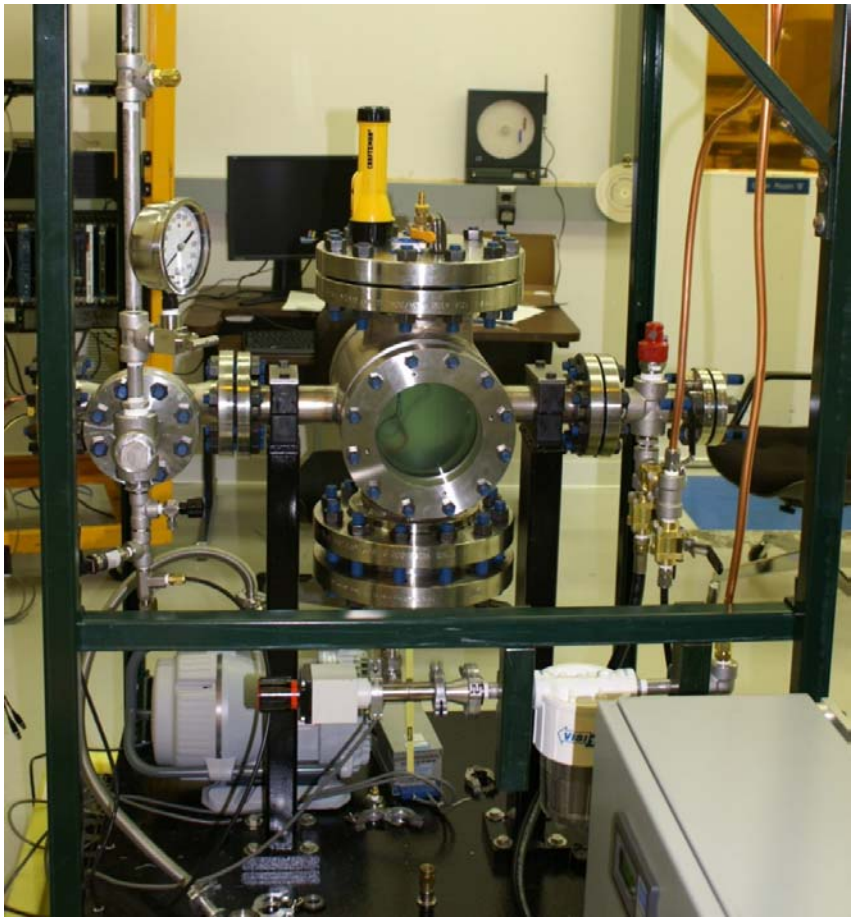


COMING ATTRACTIONS:

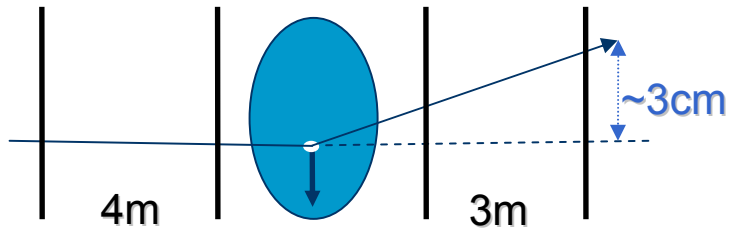
New Site in MINOS Tunnel
- o Room for muon veto
- o Clear passageway for MINERvA

Coming Attractions: nuclear recoil calibration via π^- scattering

- New Bubble Chamber optimized for calibration studies



Meson Test Beam
~1KHz 10 GeV/c
Negative Beam,
Trigger counters,
Cherenkov tagging



1mm MWPC Detectors

This technique will specifically isolate Iodine recoils near threshold

Coming Attractions:

- New proposal:
  - 30 liter (60 kg) bubble chamber…
  - Deep underground site…

THANKS !

o Fermilab Directorate (for patience, we proposed this two years ago…)

o PPD (for R&D support, Engineering, tech support…)

o Test Beam Program (logistical support, tech support)

o We're Looking Forward to Exciting New Physics